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Diffusion-weighted imaging findings of brain parenchyma in pediatric pseudotumor cerebri

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Abstract

Pseudotumor cerebri (PTC) or idiopathic intracranial hypertension (IIH) is a confounding clinical entity encompassing a variety of assumed mechanisms. The chief aim of the study was to determine brain edema by documenting the findings of diffusion magnetic resonance imaging (MRI) conducted to evaluate the brain parenchyma in patients with pediatric PTC. In this study, 19 patients participated, which were categorized into 2 groups as per Friedman's criteria. First group comprised of 11 patients diagnosed with PTC while the second group comprised of remaining 8 patients diagnosed with 'probable PTC'. Conventional MRI findings and magnetic resonance venography (MRV) findings were noted. Transverse sinus variations were grouped according to the modified Fofi criteria. The apparent diffusion coefficient (ADC) values (ADC mean, ADC min, and ADC max) of the splenium and genu of the corpus callosum, bilateral occipital, parietal, temporal, and frontal cortex and white matter along with the bilateral head of caudate nucleus, putamen and thalamus were evaluated. The control group was formed with corresponding ages and gender of the patients and the ADC values (ADC mean, ADC min, and ADC max) for brain parenchyma in same localisations of the brain were also evaluated in controls. The findings showed that there is no statistically significant difference between two groups of patients regarding their ages (p: 0.06). The mean cerebrospinal fluid (CSF) opening pressure was found to be 35.5 ± 9.0 cmH_2O and 25.5 ± 2.8 cmH_2O for first and second group respectively with significant difference ($p < 0.001$). Headache was found to be the most common symptom (50%) followed by double vision (30%). The most common conventional MRI finding was perioptic nerve sheath distension (37%). 52% children had transverse sinus hypoplasia demonstrated by MRV. The ADC values (ADC mean, ADC min, and ADC max) for brain parenchyma evaluated in various regions for the groups and controls did not show any significant difference. The detection of a high percentage of the transverse sinus variations in patients with PTC supports the finding that PTC is accompanied by secondary obstruction of the transverse sinuses. The cerebral ADC values did not differ between age and gender matched control groups, showing there is no detectable cerebral edema in PTC with diffusion MRI.

Keywords: Pseudotumor cerebri, MRI, pediatric

Introduction

Pseudotumor cerebri (PTC) or idiopathic intracranial hypertension (IIH) is a disorder of elevated intracranial pressure without any evidence of infection, vascular abnormality, space-occupying lesion, hydrocephalus or alteration of consciousness. According to 30%–96.5% reported cases, headache is the most common symptom of this condition till now. The characteristic of disease is papilledema, which is found mostly in acute presentation or bilaterally, however almost 17.8% of the patients did not have papilledema at presentation [1]. The known causes of intracranial hypertension are vitamin A intoxication, mastoid or middle ear infection, endocrine diseases like hypoparathyroidism and Morbus Addison, cerebral venous sinus thrombosis, and others. Since inaccurate diagnosis of intracranial hypertension may cause blindness, precise diagnosis and treatment based on the etiology of the intracranial hypertension is important.

Modified Dandy criteria approved in the year 1985 was used in the diagnosis which involves: 1) Cerebrospinal fluid (CSF) opening pressure of >25cmH_2O with normal composition, 2) symptoms and signs of elevated intracranial pressure such as nausea, headache,

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vomiting, papilledema, or transient visual obscurations, 3) lack of localizing neurologic signs with unilateral or bilateral abducent nerve palsy being exception, and 4) normal to small ventricles as shown by computed tomography (CT) but nowadays magnetic resonance imaging (MRI) is the preferred modality [2]. In 2013, Dandy criteria was modified which was followed with Friedman's diagnosis based on following conditions: absence of papilledema and abductive nerve paralysis along with elevated CSF pressure and detection of some of the following MRI findings: flattening of posterior sclera, flattening of pituitary gland, transverse venous sinus stenosis and the subarachnoid space distension within the optic nerve with or without tortuosity. Besides normal MRI findings and normal CSF opening pressure, he used some clinical signs of certain conditions for diagnosis of probable intracranial hypertension in patients with LP opening pressure <25 cmH_2O. For this purpose, he grouped the cases based on the clinical signs of headache (different from other types of headache specified by the international classification of headache disorder ICHD III-Beta) and papilledema and evident improvement observed following the draining of cerebrospinal fluid [3]. Rangwala in 2007 recommended the criteria for diagnosis of pediatric intracranial hypertension. According to his criteria, CSF pressure was >250 mm/H_2O in those aged 8 or above or less than 8 without papilledema, >180 mmH_2O in patients less than 8 years old with papilledema, and >76 mm/H_2O in neonates [4]. However, there are still some uncertainties in the literature regarding these criteria with uncertainties in the diagnoses [1]. Even though lower CSF pressures may have been recorded for a few patients than specified in the above criteria, they might still require medical treatment for intracranial hypertension urgently and show speedy recovery after medical treatment [3]. The primary function of lumbar puncture (LP) is to ensure that the composition of fluid is normal and if CSF pressures are high, then excessive volume is removed to make it normal.

Researchers are still working on the exploration of the mechanism behind higher CSF pressure in patients with PTC. The mechanisms being studied include the CSF hypersecretion at the choroid plexus, irregular venous pressure gradients, lower reabsorption at the arachnoid granulations, glymphatic dysfunction (due to which brain parenchyma loses metabolites), bilateral transverse sinus stenosis, and excessive collapsibility of dural sinuses [5]. The literature includes various old studies on diffusion MRI that gave variable outcomes while studying the significance of brain edema for disease etiology. It is possible to obtain non-invasive as well as in vivo information about organization of cells within the brain cortex, connection between various parts as well as brain's essential functioning and water diffusion through Diffusion MRI [6]. There are discrepant findings in the literature. The principal studies that compared IIH patients and control groups were performed by Sorensen et al. These studies suggested that the MRI of some patients depicted higher water diffusion in the periventricular region while MRI of other patients showed higher water diffusion in entire brain [7]. Higher diffusion was detected by Gideon in subcortical areas [8]. Conversely, Bastin performed diffusion-weighted imaging whereby he used diffusion gradients in three orthogonal directions. The main reason behind this was to prevent the measured mean diffusion from the impact of anisotropic diffusion [9]. He discovered IIH was not characterized with diffuse brain edema.

This study intends to detect any brain edema in pediatric patients with the condition of intracranial hypertension by determining the ADC values and consequently comparing them with the values observed in healthy controls with corresponding age and gender.

Materials and Methods

Routine MRI and magnetic resonance venography (MRV) along with CSF opening pressure measurements were done for the examination of 37 pediatric patients aged below 18 years with clinical suspicion of PTC. The standard LP procedure was used to measure CSF pressures. While measuring the CSF pressure, the patients were advised to be in the lateral decubitus position with extended head and legs. Nidazolam was used to serve the purpose of an anesthetic agent by sedated outpatient LPs. Overall, in this study, 19 patients participated, which were categorized into 2 groups according to Friedman's criteria [3]. The selection of the control group was based on criteria of patients that were had brain MRI because of sinusitis or headache and other symptoms and signs unrelated to intracranial hypertension and age and gender matched for the first and second group and the control group showed normal MRI. In the control group, children having symptoms like the symptoms of high intracranial pressure were not included. After ophthalmologic assessment, all patients showed papilledema.

MRV examinations were retrospectively reviewed for the presence of anatomical sinus variations or detection of thrombus. The variations in the vein morphology were made according to the modified Fofi criterias [10]. TS morphology was graded using modified Fofi criteria; grade 0= TS symmetry or TS asymmetry 10% compared with the contralateral TS; grade 1 = TS asymmetry >10% and ≤50% compared with the contralateral TS; grade 2 = TS asymmetry >50% compared with the contralateral TS; grade 3 = aplasia, or TS signal absent. TS hypoplasia was defined as the indexed TS being >50% of the contralateral TS, including grade 2 or 3. The ADC mean, ADC min, and ADC max values of the splenium and genu of the corpus callosum, bilateral occipital, parietal, temporal, and frontal cortex and white matter along with the bilateral head of caudate nucleus, putamen and thalamus were evaluated. The ROIs had been localized in axial T2 weighted scans positioned in ADC maps (Figure 1). In addition, the traditional MRI results were recorded. If the additive width of the cerebrospinal fluid within the mid-portion of the optic nerve sheath exceeded the width of the corresponding optic nerve signal, which was evaluated on the axial T2-weighted scans and confirmed on the coronal STIR scans accepted as perioptic nerve sheath distension [11]. A central point of the pituitary gland where optic chiasma or the stalks are evident is considered on coronal T2-weighted scans in order to evaluate the size of pituitary gland. We examined superior ophthalmic vein (SOV) enlargement and flattening of the globe as well.

On the basis of the body mass index (BMI) percentile, which are >91st, >98th, and >99.6th, the groups were categorized as overweight, obese, and severely obese respectively. The "pre-pubertal" status was given to females younger than 11 years and males younger than 12 years.

We used mean ± standard deviation to describe the continuous variables while we used number and percentages (%) to describe

frequency variables. In order to assess normally distributed variables, we made use of Shapiro Wilk test. The Mann Whitney U test was used to evaluate non-normally distributed measurement by comparing groups. The Student T test was utilized to evaluate normally distributed measurement by comparing groups. In all statistical tests, a benchmark p value < 0.05 was set as statistical significance indicator. All statistical analysis was carried out on a personal computer by SPSS version 22 for Windows (SPSS Inc, Chicago, IL, USA).

The ethics committee at a local university hospital approved this retrospective research study.

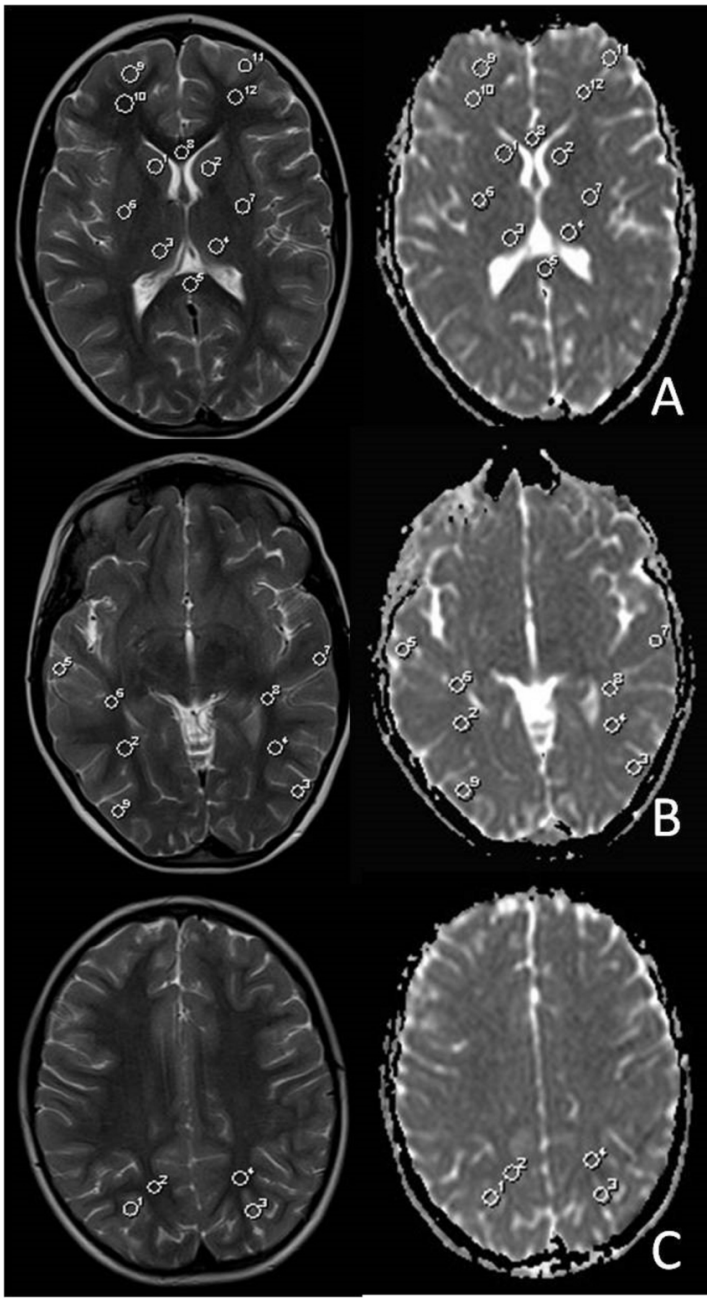

Figure 1. The axial T2 weighted images and ADC maps of 108-month-old girl patient with PTC. ROIs were drawn in bilateral putamen, caudate nucleus head, thalamus, corpus callosum splenium and genu, frontal cortical and subcortical white matter (A), bilateral temporal and occipital cortical and subcortical white matter (B), and bilateral parietal cortical and subcortical white matter (C) in T2 weighted images which were placed automatically on same localization and same size on ADC maps.

Results

Out of 37 patients, 13 patients without DWI, 3 patients with a normal pressure of CSF, and 1 patient with diffuse encephalitis and 1 patient with subacute cerebral vein thrombosis were omitted from the study. First group comprised of 11 patients diagnosed with PTC while the second group comprised of remaining 8 patients diagnosed with probable PTC with lower CSF opening pressures [3]. The first and second groups comprised of 11 children (4 males and 7 females) and 8 children (5 males and 3 females) respectively. The mean age for first and second groups was 137.6 ± 56.1 and 82.8±59.6 months respectively. The findings indicated that there is no statistically significant difference among groups regarding patients' age (p= 0.06) and gender (p= 0.37). The mean CSF opening pressure was 35.5 ± 9.0 cmH_2O and 25.5 ± 2.8 cmH_2O for first and second group respectively with significant statistical difference ($p < 0.001$) as the groups were made partly based on the difference in CSF pressures. 7 children had reached puberty. Number of children belonging to overweight and obese groups was both three. In all patients, the CSF fluid had a normal composition. All patients had a normal cranial MRI, except for one with periventricular mild hyperintensity because of periventricular leukomalacia. There were no infarctions detected. Seven patients (six from group 1 and one from group 2) had perioptic nerve sheath distension. Two patients (one from group 1 and one from group 2) were detected with partial empty sella. No enlargement of the SOV or flattening of the posterior globe was detected. Headache was found to be the most common symptom (50%) followed by double vision (30%). The groups also did not show any significant difference regarding types of symptoms and their MRI findings (perioptic nerve fluid distension and partial empty sella). Any cerebral venous sinus (CVS) anomalies that were present were noted immediately. The transverse sinus morphology variations was found to be the most common. According to the modified Fofi criteria, the first group was formed with 7 and the second was formed with 3 patients with transverse sinus hypoplasia. All the patients were treated medically. Some clinical and radiological features of the study groups were shown in Tables 1 and 2.

The groups and the controls with corresponding ages did not show any statistically significant difference in the ADC values (ADC mean, ADC min, and ADC max) evaluated for brain parenchyma in various parts. Usually, the second group shows higher ADC values as compared to the first one; the possible reason for this difference may be patients' age (Table 3 and 4).

Discussion

The fact that PTC causes substantial morbidity as well as permanent vision loss if left untreated, makes early diagnosis and intervention critical. For the patients suffering from PTC, the common neuroimaging results include transverse venous sinus stenosis, posterior globes' flattening, empty sella, cerebellar tonsillar herniation, optic nerve sheaths (ONSs)'s distention, and meningocele [12]. It is significant to note that, while the absence of one or two of the above-mentioned symptoms does not rule out the possibility of PTC, the presence of one or more of them greatly increase the likelihood of a PTC diagnosis. In our study, 7 (36%) of the patient had perioptic nerve sheath distension and 2 of them had also partial empty sella. Our study involved children who respond differently to high intracranial pressure as compared

Table 1. Some clinical and MRI characteristics of study groups

Case	Age (month)	Sex	Symptoms	MRV	CSF pressure	MRI Findings	Group
1	41	F	Headache	Right transverse sinus hypoplasia (grade 3), right occipital sinus	30	Perioptic nerve sheath distension	1
2	201	F	Difficulty in urination	7 mm sized arachnoid granulation in left transverse sinus	60	Perioptic nerve sheath distension	1
3	204	F	Headache and dizziness	Right transverse sinus hypoplasia (grade 3), right occipital sinus, lateral part of stenosis of left transverse sinus	31		1
4	144	F	Headache	Normal	39		1
5	168	M	Convulsion	Left transverse sinus hypoplasia (grade 2)	30		1
6	60	M	Internal strabismus, double vision	Left transverse sinus hypoplasia (grade 3)	29	Perioptic nerve sheath distension,	1
7	180	F	Headache	Normal	30	Perioptic nerve sheath distension,	1
8	156	F	Headache and double vision	Bilateral transverse sinus lateral stenosis, right transverse sinus hypoplasia (grade 2)	40		1
9	168	M	Headache	Right transverse sinus hypoplasia (grade 2)	38		1
10	84	F	Ptosis and diplopia	Bilateral occipital sinus, Left transverse sinus hypoplasia (grade 2)	32	Perioptic nerve sheath distension,	1
11	108	M	Blurred vision	Left transverse sinus asymmetry (grade 1)	32	Perioptic nerve sheath distension, partial empty sella	1
12	156	M	Headache	Left transverse sinus hypoplasia (grade 2)	25		2
13	29	F	Unsteady gait	Normal	28		2
14	25	F	Internal strabismus and double vision	Bilateral occipital sinus, bilateral sinus rectus	19		2
15	108	F	Headache and double vision	Right transverse sinus hypoplasia (grade 2)	27	Perioptic nerve sheath distension, partial empty sella	2
16	180	M	Headache	Right transverse sinus asymmetry (grade 1)	26		
17	72	M	Headache	Left transverse sinus asymmetry (grade 1)	25		
18	32	M	Convulsion	Normal	27		
19	60	M	Internal strabismus and double vision	Left transverse sinus hypoplasia (grade 2)	27		

Table 2. Some characteristics of the patients

Variables		**Group 1 (n:11) n (%)**	**Group 2 (n:8) n (%)**	**p**
Age (month)		137.6±56.1	82.8±59.6	0.06
CSF pressure (cmH_2O)		35.5 ±9.0	25.5±2.8	<0.001
Sex	Female	7 (63.6)	3 (37.5)	0.37*
	Male	4 (36.4)	5 (62.5)	
Perioptic nerve sheath distension	Present	6 (54.5)	1 (12.5)	0.14*
	Absent	5 (45.5)	7 (87.5)	
Partial empty sella	Present	1 (9.1)	1 (12.5)	1.00*
	Absent	10 (90.9)	7 (87.5)	
Transvers sinus hypoplasia	Present	7 (63.6)	3 (37.5)	0.37*
	Absent	4 (36.4)	5 (62.5)	
Transvers sinus stenosis	Present	2 (18.2)	0 (0.0)	0.48*
	Absent	9 (81.8)	8 (100.0)	

*Fisher's Exact Test

Table 3. The comparison of the ADC values between first group and their controls

	ADCmin			ADCmean			ADCmax		
	Group 1	**Control 1**	**p**	**Group 1**	**Control 1**	**p**	**Group 1**	**Control 1**	**p**
RFC	742.3	795.7	0.135	836.6	852.40	0.661	944.3	965.7	0.404
RFW	739.8	698.3	0.204	797.4	815.88	0.553	873.8	918.7	0.180
LFC	691.3	748.1	0.118	817.9	844.63	0.259	888.8	907.6	0.619
LFW	728.5	693.6	0.295	793.6	803.54	0.682	872.8	885.8	0.685
RCH	683.7	686.8	0.895	749.0	775.91	0.098	823.8	843.5	0.504
LCH	6465.7	670.6	0.843	726.9	754.68	0.173	803.7	817.0	0.640
RP	672.0	684.4	0.568	748.5	765.69	0.414	808.4	843.6	0.234
LP	661.9	600.2	0.015*	720.2	718.89	0.907	769.0	817.2	0.553
RT	703.7	669.9	0.103	761.9	782.61	0.118	837.0	862.0	0.396
LT	711.5	692.6	0.320	777.5	780.19	0.867	842.5	848.1	0.813
CCG	685.3	636.7	0.162	790.6	774.33	0.557	896.7	881.2	0.745
CCS	700.6	678.2	0.446	799.9	799.10	0.972	892.6	920.3	0.555
RTC	761.3	763.9	0.910	840.5	862.10	0.430	950.8	948.4	0.670
RTW	779.9	711.4	0.064	836.5	808.83	0.436	910.0	898.8	0.798
LTC	750.2	731.4	0.526	821.4	847.68	0.353	898.8	933.0	0.318
LTW	751.4	727.8	0.535	817.4	808.90	0.798	889.8	889.6	0.992
ROC	761.6	769.3	0.714	891.4	851.61	0.175	919.9	925.18	0.864
ROW	800.5	745.3	0.073	836.2	808.73	0.270	930.5	880.55	0.167
LOC	811.5	776.4	0.156	874.4	852.28	0.331	918.0	934.91	0.570
LOW	745.0	755.0	0.777	832.0	841.21	0.837	863.6	912.64	0.173
RPC	774.6	790.7	0.584	894.4	865.66	0.321	960.7	951.81	0.791
RPW	760.2	743.9	0.500	831.2	812.35	0.519	905.9	887.27	0.572
LPC	820.5	788.6	0.310	882.2	880.83	0.956	966.3	967.36	0.976
LPW	777.2	766.0	0.712	822.7	840.65	0.526	904.7	909.36	0.901

Table 4. The comparison of the ADC values between second group and their controls

	ADCmin			ADCmean			ADCmax		
	Group 2	**Control 2**	**p**	**Group 2**	**Control 2**	**p**	**Group 2**	**Control 2**	**p**
RFC	809.3	809.7	0.988	885.9	909.28	0.464	961.6	997.6	0.311
RFW	814.6	741.3	0.100	892.9	837.70	0.202	973.8	928.3	0.340
LFC	762.4	779.3	0.626	855.9	898.87	0.356	944.4	934.5	0.790
LFW	767.7	709.0	0.215	856.0	815.37	0.426	949.4	880.4	0.232
RCH	722.4	704.2	0.628	805.5	785.43	0.571	880.3	888.3	0.837
LCH	697.7	675.4	0.627	789.3	775.62	0.708	893.7	898.7	0.886
RP	705.4	666.6	0.332	772.4	760.31	0.737	848.1	844.8	0.935
LP	717.1	675.0	0.131	783.1	764.60	0.447	763.5	849.5	0.346
RT	719.8	658.5	0.137	796.9	762.64	0.307	864.3	864.0	0.992
LT	723.6	696.3	0.407	795.3	774.61	0.469	872.3	859.4	0.636
CCG	729.1	637.3	0.079	840.4	772.43	0.174	964.7	933.7	0.619
CCS	729.5	689.0	0.399	842.5	776.21	0.128	959.7	876.6	0.136
RTC	819.0	788.0	0.446	902.9	878.71	0.460	979.7	953.3	0.887
RTW	714.3	758.7	0.632	851.5	842.43	0.342	940.1	939.8	0.995
LTC	804.2	754.3	0.133	869.5	862.55	0.799	953.2	955.1	0.950
LTW	785.0	759.3	0.584	878.3	865.81	0.706	967.6	992.2	0.406
ROC	784.6	785.7	0.956	845.7	852.42	0.742	934.3	922.0	0.658
ROW	771.1	797.5	0.402	852.6	861.41	0.791	918.3	931.4	0.744
LOC	829.2	795.0	0.081	895.0	883.36	0.556	947.7	970.1	0.500
LOW	796.3	756.2	0.130	844.0	838.83	0.811	889.1	923.2	0.298
RPC	829.0	827.8	0.973	883.2	895.36	0.714	966.4	950.07	0.642
RPW	849.8	819.5	0.565	924.8	887.01	0.455	1005.6	948.3	0.276
LPC	862.7	827.1	0.253	927.2	900.80	0.492	1012.2	968.3	0.238
LPW	831.0	797.0	0.442	914.0	893.93	0.644	967.6	958.6	0.829

ADC: Apparent diffusion coefficient, RFC: Right frontal cortex, RFW: Right frontal white matter, LFC: Left frontal cortex, LFW: Left frontal white matter, RCH: Right head of caudate nucleus, LCH: Left head of caudate nucleus, RP: Right putamen, LP: Left putamen, RT: Right thalamus, LT: Left thalamus, CCG: Genu of corpus callosum, CCS: Splenium of corpus callosum, RTC: Right temporal cortex. RTW: Right temporal white matter, LTC: Left temporal cortex, LTW: Left temporal white matter, ROC: Right occipital cortex, ROW: Right occipital white matter, LOC: Left occipital cortex, LOW: Left occipital white matter, RPC: Right parietal cortex, RPW: Right parietal white matter, LPC: Left parietal cortex, LPW: Left parietal white matter.

to adults and also show tissue compatibility, which may be the reason behind lower frequencies of MRI findings. In literature it was considered that the conventional MRI findings may also be a beneficial diagnosing tool for following post-treatment patients with PTC, especially as the pituitary gland's height in midsagittal images and the thickness of optic nerve sheath tend to be reversible morphometric MRI characteristics [13]. Furthermore, the study by Lirng showed positive correlation between the SOV diameter and the intracranial pressure demonstrated by MRI. SOV dilation can be considered as the indication of the increased intracranial pressure [14]. In our study, there was not any patient with SOV dilatation.

Our study showed 52,6% children had transverse sinus hypoplasia/stenosis and only 10,5% had transverse sinus stenosis demonstrated by MRV. The increased resistance in venous drainage because of stenosis or hypoplasia with a resulting diversion of drainage into epidural vessels with an associated increase in intracranial pressure is subject to extensive debate and research efforts because of potential therapeutic implications [15]. Significant evidence indicates that PTC is accompanied by secondary obstruction of the transverse sinuses. Actually, it is still not known if the sinus stenosis causes or develops from intracranial hypertension. In cerebral vein thrombosis, the prevalent hypothesis is that elevated venous pressure leads to lower reabsorption; the primary etiology of PTC is thus increased intracranial pressure [16]. Compared to some reports, it was stressed that PTC elevates sinus pressure which consequently obstructs sinus. This condition may be treated by using LP for emptying CSF to minimize venous sinus pressure [17]. A 35 percent occurrence of cerebral venous sinus thrombosis in PTC was found by Turay and colleagues, highlighting the need to consider the risk of thrombosis development in patient groups with PTC [18]. In the study by Higgins et al., comparison of 20 patients with PTC with 40 asymptomatic volunteers was carried out and significant signal gaps (which is defined as a lack of high signal intensity in MRV) was observed in most patients with PTC whereas the control group lacked signal gap. This may be attributed to venous outflow obstruction that leads to the PTC patient's etiopathogenesis [19].

Our study showed a lack of significant difference in the ADC values evaluated for first and second groups compared to age and gender-matched controls despite the fact that both groups had statistically different values of CSF pressure. Such a result may suggest that although the CSF pressure increases, there are no changes in cerebral ADC values that may indicate cerebral edema. One theory is that IIH is caused by cerebral edema. Sahs and Joynt [20] reported an increase in both extracellular and intracellular fluid in brain biopsies of patients with IIH. However, other investigators did not find edema in their patients' pathology specimens [21]. Some MRI studies in the literature relating to intracranial hypertension seek to understand cerebral diffusion and perfusion alterations. After Sorensen and Gideon found increased water diffusion in the brain, Bastin's MRI study found that diffuse brain edema was not a feature of IIH [9]. Bicakci studied the diffusion and perfusion MRI findings of 16 patients with IIH and of 16 age-, sex-, and weight-matched normal individuals as a control group. They did not conduct quantitative assessment in their diffusion study. They found that magnetic resonance angiography (MRA), MRV, DWI, and ADC maps were also normal in all groups. There were statistically significant decreases in cerebral blood flow in six patients, whereas nonsignificant increase in two were detected in a perfusion MRI study. They postulated that long-standing increased CSF pressure in six of their patients might have led to a decrease in cerebral blood flow [22]. Bateman noted a 46% increase in total blood flow in five patients with IIH and decreased blood flow in seven patients with secondary intracranial hypertension due to thrombosis and arachnoid granulation in one patient. The author suggested that significant increase in cerebral blood flow might be due to a primary failure of autoregulation in IIH [23]. Owler studied the diffusion tensor imaging (DTI) of five patients with IIH and relied on DTI at 3 T. They found a small but significant increase in anisotropy accompanied by a small but significant decrease in trace in the putamen and head of the caudate nucleus. No significant changes were demonstrated in the thalamus, cerebral white matter, or cortical regions, supporting Bastin's diffusion MRI study [24]. Schmidt et al. demonstrated that IIH with visual disturbances was associated with microstructural abnormalities in optic nerves, likely from chronically elevated CSF pressure. By contrast, systematic regional variations between IIH patients and controls were neither observed in the whole brain analysis nor in the optic radiation [25]. In 2019, Sarica et al. indicated that there was significant DTI alteration in periventricular white matter microstructure in patients with IIH and that it consisted of lower values of mean, axial, and radial diffusivity without any change in fractional isotropy. These changes are partially reversible when CSF pressure is normalized after medical treatment, suggesting that DTI may be used for evaluating disease progression or resolution and to assess treatment efficacy [26]. Another study by Aslan revealed no significant difference between the ADC min, ADC max, and ADC mean values obtained from certain diverse brain regions of intracranial hypertension patients compared to the normal healthy control group of nonpediatric age [27]. In our study, all of our patients displayed no differences in ADC values in similar brain regions compared with their control groups as in Aslan's study.

Our study involves certain limitations. The first limitation is associated with inclusion of a limited number of participants in the study. The future studies should aim to take a large number of patients into consideration as it will be beneficial for the confirmation of this study. Second, the slice thickness of MRI in the current study was 3-4 mm. Future studies are aimed to use thinner sections which will provide detailed orbital imaging. The shape and size of the pituitary gland should also be considered as it changes with respect to the age of healthy children. This implies that future research that associates pituitary gland size with hormone levels in pediatric intracranial hypertension will be more conclusive. Another limitation is DTI is more advanced imaging technique to demonstrate cerebral edema, which was lacking in our study because of its retrospective nature.

Conclusion

In conclusion, the rate of transverse sinus hypoplasia and stenosis in all patients with PTC was 52,6% and 10,5% respectively. The high frequency of the cerebral venous variations in these patients raises the question of whether cerebral venous variations are the result or the cause of the diseases and whether MRV must be implemented for all patients with clinical suspicion of intracranial hypertension patients. Additionally, no ADC difference was found between the first and second groups and their age and gender matched controls, demonstrating that when CSF opening pressure were increased, there was no increase in ADC values compared with controls representing lacking of edema in pediatric patients in diffusion MRI. Further studies using DTI and large series are required to determine whether there is a demonstrable difference in increased diffusion to exclude brain edema.

Conflict of interests
The authors declare that they have no competing interests.

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The financial support for this study was provided by the investigators themselves.

Ethical approval

The ethics committee at a local university hospital approved this retrospective research study.Ethics comittee number is OMUKAEK 2020/605

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